



Lava Layering

Grades: K-8

Prep Time: ~10 Minutes

Lesson Time: ~90 Minutes

WHAT STUDENTS DO: Sequence Lava Flow Events using Drill Cores and Cuts.

Students will sequence lava flows produced by multiple eruptions. Baking soda, vinegar, and play dough, are used to model fluid lava flows. Students will be asked to observe where the flows travel, make a model, and interpret the stratigraphy.

NRC CORE & COMPONENT QUESTIONS

WHAT IS THE UNIVERSE, AND WHAT IS EARTH'S PLACE IN IT?

NRC Core Question: ESS1: Earth and Space Science

HOW AND WHY IS EARTH CONSTANTLY CHANGING

NRC Core Question: ESS2: Earth and Space Science

How do people reconstruct and date events in Earth's planetary history?

NRC Component Question: ESS1C: The History of Planet Earth

How do Earth's major systems interact?

NRC Component Question: ESS2A: Earth Materials and Systems

INSTRUCTIONAL OBJECTIVES

Students will be able

IO1: to reconstruct
geologic events of a
series of lava flows
using relative dating
techniques



1.0 About This Activity

Mars lessons leverage *A Taxonomy for Learning, Teaching, and Assessing* by Anderson and Krathwohl (2001) (see *Section 4* and *Teacher Guide* at the end of this document). This taxonomy provides a framework to help organize and align learning objectives, activities, and assessments. The taxonomy has two dimensions. The first dimension, cognitive process, provides categories for classifying lesson objectives along a continuum, at increasingly higher levels of thinking; these verbs allow educators to align their instructional objectives and assessments of learning outcomes to an appropriate level in the framework in order to build and support student cognitive processes. The second dimension, knowledge, allows educators to place objectives along a scale from concrete to abstract. By employing Anderson and Krathwohl's (2001) taxonomy, educators can better understand the construction of instructional objectives and learning outcomes in terms of the types of student knowledge and cognitive processes they intend to support. All activities provide a mapping to this taxonomy in the Teacher Guide (at the end of this lesson), which carries additional educator resources. Combined with the aforementioned taxonomy, the lesson design also draws upon Miller, Linn, and Gronlund's (2009) methods for (a) constructing a general, overarching, instructional objective with specific, supporting, and measurable learning outcomes that help assure the instructional objective is met, and (b) appropriately assessing student performance in the intended learning-outcome areas through rubrics and other measures. Construction of rubrics also draws upon Lanz's (2004) guidance, designed to measure science achievement.

How Students Learn: Science in the Classroom (Donovan & Bransford, 2005) advocates the use of a research-based instructional model for improving students' grasp of central science concepts. Based on conceptual-change theory in science education, the 5E Instructional Model (BSCS, 2006) includes five steps for teaching and learning: Engage, Explore, Explain, Elaborate, and Evaluate. The Engage stage is used like a traditional warm-up to pique student curiosity, interest, and other motivation-related behaviors and to assess students' prior knowledge. The Explore step allows students to deepen their understanding and challenges existing preconceptions and misconceptions, offering alternative explanations that help them form new schemata. In Explain, students communicate what they have learned, illustrating initial conceptual change. The Elaborate phase gives students the opportunity to apply their newfound knowledge to novel situations and supports the reinforcement of new schemata or its transfer. Finally, the Evaluate stage serves as a time for students' own formative assessment, as well as for educators' diagnosis of areas of confusion and differentiation of further instruction. This five-part sequence is the organizing tool for the Imagine Mars instructional series. The 5E stages can be cyclical and iterative.



2.0 Materials

Required Materials

Please supply:

For Volcano Building (per group of students)

- 1 paper cup, 100ml (4oz) size, cut down to a height of 2.5cm
- 2 paper cups, 150 - 200ml (6-8 oz) size.
- Cardboard, ~ 45cm square (can substitute cookie sheet or a box lid)
- Play Dough or soft clay – at least 4 - 2 inch (2oz) balls, each a different color
- Tape (Scotch)
- Spoon
- Baking soda (1/4 cup)
- Vinegar, 100-150ml (4-6 oz) depending on number and size of flows
- Paper towels
- Marker or grease pencil

For observing and drawing volcanic layers (per group of students)

- Paper and pencil
- Colored pencils or crayons (3-4 colors)
- 2 Metric rulers
- Straight edge for cutting (such as dental floss or plastic picnic knife)
- Large width straw per student (5cm long)
- 5-10 toothpicks

Please Print:

From Student Guide:

- | | |
|-----------------------------------|-----------------|
| (A) Making and Mapping a Volcano | – 1 per student |
| (B) Student Sheet #1 | – 1 per student |
| (C) Relative Age Dating Technique | – 1 per group |
| (D) Mapping an “Unknown” Volcano | – 1 per group |
| (E) Student Sheet #2 | – 1 per student |
| (F) Geologic Map of Pavonis Mons | – 1 per group |

Optional Materials

For Volcano Building:

- food coloring to color the vinegar if desired, 4 colors; such as red, yellow, blue, green

**From Teacher Guide:**

- (G) Single Sheet Option for Student Sheet #1 and Student Sheet #2
- (H) Volume Reference Page
- (I) Volcano Science Content Reference Page
- (J) Relative Dating science Content Reference Page
- (K) Grand Canyon Stratigraphic Column

3.0 Vocabulary

Core Sampling	a cylindrical core removed from a drill hole that can be used to identify layers unseen below the Earth's surface
Eruption	ejection of molten rock, steam, or ash
Explanations	logical descriptions applying scientific information
Geologic Mapping	a sequence of event that are organized using the visual characteristic changes among rock layers
Lava Flows	a bulbous or ropey igneous rock structure that begins at a volcanic vent
Layers	a bed of rock
Models	a simulation the helps explain natural and man-made systems and see possible flaws
Predict	a declaration about what will happen based on reason and knowledge
Relative Dating	a sequence of events that are organized using their relationship to each other
Stratigraphy	a branch of geology where rock layers are classified, named, and correlated
Source	area that is an origin for an event
Volcano	a vent in the earth's crust where lava, steam, and ash erupts



4.0 Instructional Objectives, Learning Outcomes, Standards, & Rubrics

Instructional objectives, standards, and learning outcomes are aligned with the National Research Council's *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*, which serves as a basis for upcoming "Next-generation Science Standards." Current National Science Education Standards (NSES) and other relevant standards are listed for now, but will be updated when the new standards are available.

The following chart provides details on alignment among the core and component NRC questions, instructional objectives, learning outcomes, and educational standards.

- Your **instructional objectives (IO)** for this lesson align with the NRC Framework and education standards.
- You will know that you have achieved these instructional objectives if students demonstrate the related **learning outcomes (LO)**.
- You will know the level to which your students have achieved the learning outcomes by using the suggested **rubrics** (see Teacher Guide at the end of this lesson).

Quick View of Standards Alignment:

The Teacher Guide at the end of this lesson provides full details of standards alignment, rubrics, and the way in which instructional objectives, learning outcomes, 5E activity procedures, and assessments were derived through, and align with, Anderson and Krathwohl's (2001) taxonomy of knowledge and cognitive process types. For convenience, a quick view follows:



WHAT IS THE UNIVERSE, AND WHAT IS EARTH'S PLACE IN IT?

NRC Core Question: ESS1: Earth and Space Science

HOW AND WHY IS EARTH CONSTANTLY CHANGING

NRC Core Question: ESS2: Earth and Space Science

How do people reconstruct and date events in Earth's planetary history?

NRC Component Question: ESS1C: The History of Planet Earth

How do Earth's major systems interact?

NRC Component Question: ESS2A: Earth Materials and Systems

Crosscutting Concepts:

*Patterns
Cause and Effect
Energy and Matter*

Instructional Objective <i>Students will be able</i>	Learning Outcomes <i>Students will demonstrate the measurable abilities</i>	Standards <i>Students will address</i>	<i>Rubrics in Teacher Guide</i>
IO1: to reconstruct geologic events of a series of lava flows using relative dating techniques	LO1a: to construct a geologic map of a volcano model LO1b. to use geologic sampling and relative dating techniques LO1c. to justify an explanation for the geologic mapping and history of the volcano model	NSES: UNIFYING CONCEPTS & PROCESSES: K-12: Evidence, models, and explanations NSES (D): EARTH AND SPACE SCIENCE: Structure of the Earth System Grades 5-8: D1c, D1d Earth's History Grades 5-8: D2a The Origin and Evolution of the Earth System Grades 9-12: D3b, D3c	

This activity also aligns with:

21ST CENTURY SKILLS

- Critical Thinking and Problem Solving
- Communication
- Collaboration
- Initiative and Self-Direction



5.0 Procedures

PREPARATION (~45 minutes)

Preparing the home made play dough

- A. Stove-top recipe (best texture and lasts for months when refrigerated in an airtight container:

<i>2 cups flour</i>	<i>1-cup salt</i>	<i>4 teaspoons cream of tartar</i>
<i>1/3-cup oil, scant</i>	<i>2 cups cold water</i>	<i>food colorings (20 drops or less)</i>

- You will need 4 colors total.
- Make this large batch one color or divide ingredients in half to make 2 colors.
- Combine ingredients and cook mixture in a large saucepan, stirring constantly, until the dough forms a ball.
- Turn dough out onto a floured surface to cool.

- B. No-cooking recipe:

<i>2 cups flour</i>	<i>1-cup salt</i>
<i>6 teaspoons cream of tartar or alum</i>	<i>2 tablespoons oil</i>
<i>1-cup cold water</i>	<i>food colorings (20 drops or less)</i>

- You will need 4 colors total.
- Make this large batch one color or divide ingredients in half to make 2 colors.
- Mix ingredients and kneed until smooth and elastic.
- Store in airtight containers.

Printing:

- C. Please print handouts (A) – (F) in the Student Guide

STEP 1: ENGAGE (~5 minutes)

Visualizing Cake Layers

Read the following to the students:

- A. **Fiction Story:** You have baked a cake for your friend's birthday. It has 3 layers; all different flavors and covered in chocolate icing. When you bring the cake out to your friend, you are asked, "What flavors are in the cake." The flavors and their order are a mystery to everyone in the room but you.

This is similar to rock layers. Often times, we are only able to see the top layer of rock or even just the soil on top, we aren't really sure what layers are below. By the end of this activity, you will be able to explain to your friends the types of relative dating techniques they can use to determine what flavors exist and what order they are in.



🍏 Curiosity Connection Tip: For making a connection to NASA's Mars Rover "Curiosity," please show your students additional video and slideshow resources, such as Choosing a Landing Site at: <http://mars.jpl.nasa.gov/participate/marsforeducators/soi/>

STEP 2: EXPLORE (~35 minutes)

Making a Volcano

- A. Hand out the (A) *Making and Mapping a Volcano*. Ask students to read and answer the "Before you get started" question.
- B. Have each group of students collect materials.
- C. Students will be using the short 2.5 cm cup as the vent of the volcano for each eruption
- D. The students will create an eruption using the vinegar and baking soda and drawing a line around the edge of their eruption using a pencil or marker.
- E. Once the line is drawn, students will mop up the liquid and cover the lava flow area with one color of the pre-made play dough.
- F. They will then repeat this process 2 more times, each time with a different color of play dough, each time recording the shape, direction, color and thickness on pg 3 of (A) *Making and Mapping a Volcano* sheet.
- G. Ask groups to draw a map (birds-eye) view of the volcano page 4 of the (A) *Making and Mapping a Volcano* sheet. This may be made in actual size or they may make a scale drawing.
- H. The map should include a North direction arrow.
- I. Students will need to make careful observations and measurements to map the volcanoes accurately. Color and label the map using colored pencils or crayons.
- J. Hand out (B) *Student Sheet #1*. Allow students time to complete the sheet using the (C) *Relative Dating Techniques* sheet.
- K. Student teams will trade volcanoes so that they will map a volcano with an "unknown" history. They may give the volcano a name if desired.
- L. Hand out (D) *Mapping an "Unknown" Volcano*. Ask groups to draw a map (birds-eye) view of the "unknown" volcano on pg 2. The map should include a North direction arrow. Color and label the map.



- M. Lead the students to question what they cannot see below the surface. Where do the flows extend under the exposed surface? Lead them to name ways they can see what is below the surface without lifting the play dough. They may suggest drill holes (core samples), river erosion and bank exposure, earthquakes, or road cuts and other excavations.
- N. Have groups make a plan that shows on their map where they want to put the subsurface exposures by making marks on their drawing on pg 2 of the *(D) Mapping an "Unknown" Volcano*.
- O. They should indicate how the proposed cores and cuts will maximize the information they might gain from excavations. Limit the number of exposure each group may use (i.e. – five drill cores, one road cut and one river erosion.)
- P. Students will observe the hidden layers through the cuts and cores. They will use these observations to draw dotted lines on the map indicating the approximate or inferred boundaries of the subsurface flows and to hypothesize the sequence of layers in the geologic column on pg 2 of the *(D) Mapping an "Unknown" Volcano*.

Teacher Tips:

1. For younger students, it may be beneficial to have premeasured baking soda and vinegar cups available. This will help with resource management and reduce mess.
2. It is recommended that students spoon out the excess vinegar after each eruption. They may also add fresh baking soda in between eruptions.
3. While students are marking lava flows, they should also mark across the previous play dough layers.
4. To conserve dough, reduce the number of eruptions to 3.
5. To conserve the number of photocopies, the *(C) Relative Age Dating Techniques* sheets can be photocopied and laminated with 1 copy per group of students for reuse each school year.

STEP 3: EXPLAIN (~15 minutes) **Create a Geologic Column**

- A. Students will draw a geologic column using colored pencils or crayons demonstrating the history of the area showing the oldest geologic activity at the bottom and youngest at the top.



🍏 **Teacher Tip:** Math classes may try to determine the area of the various eruptions using geologic map developed from core sampling and road/river cuts. (See (H) *Volume Reference Page* at the end of the lesson). Additional science content is included at the end of the lesson. This information would best be used toward the end of the activity when student interest is peaked and they want to know more about volcanoes, relative dating, and stratigraphy. (See (I) *Volcano Science Content Reference Page*, (J) *Relative Dating Science Content Reference Page*, and (K) *Grand Canyon Stratigraphic Column*.)

STEP 4: ELABORATE (~15 minutes)

Geologic Mapping from Satellite

- A. Explain to students that we don't always have the luxury of a core sample or road/river cuts to help us put together a geologic history. When we observe other planets and moons using satellite imagery, we are only able to observe the lava flows from a bird's eye view, similar to the first step of determining the geologic history of their "unknown" volcano.
- B. Students will use a geologic map from a satellite image of Mars volcanoes (F) *Geologic Map of Pavonis Mons*, in an attempt to put together a geologic history of the volcano without the use of core samples or road cuts.
- C. Ask students to work together as a group to determine the geologic history of the volcano. As they work, they may want to draw and label the image.
- D. Have students report their findings along with a description of the evidence they used to determine the history of the volcano.

🍏 **Teacher Tip:** A copy of the geologic map is provided at the end of the lesson plan. A class set is recommended, printed in color and laminated.

STEP 5: EVALUATE (~10 minutes)

Evaluate Proposed Solutions using Criteria

- A. Student groups will share their original lava flow drawings from (A) *Making and Mapping a Volcano* with the group working with their volcano.
- B. Ask student groups to compare the history they have determined with the original history drawn from the original group that made the volcano.
- C. Students will complete the (E) *Student Sheet #2* based on these observations.
- D. Use provided rubric to assess student progress.



Teacher Tip: (G) *Single Sheet Option of Student Sheet #1 and Students Sheet #2* has been provided at the end of this lesson that can be used to conserve paper. Students can use the essay question writing prompts provided to answer on their own separate sheet of paper.

6.0 Extensions

Make connections to plate tectonics lessons

- A. Difference between shield and stratovolcanoes
- B. Types of eruptions
- C. Types of lava's
- D. Where these volcanoes are typically found
- E. Earth/Mars comparisons
 - 1. Earth contains both shield and stratovolcanoes
 - 2. Earth has plate tectonics and local tectonism
 - 3. Mars mainly has shield volcanoes
 - 4. Mars lacks plate tectonics, but does have local tectonism

7.0 Evaluation/Assessment

Use the (L) *"Lava Layering" Rubric* as a formative and summative assessment, allowing students to improve their work and learn from mistakes during class. The rubric evaluates the activities using and National Science Education Standards.



8.0 References

- Anderson, L.W., & Krathwohl (Eds.). (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives*. New York: Longman.
- Bybee, R., Taylor, J., Gardner, A., Van Scotter, P., Carson Powell, J., Westbrook, A., Landes, N. (2006) *The BSCS 5E instructional model: origins, effectiveness, and applications*. Colorado Springs: BSCS.
- Donovan, S. & Bransford, J. D. (2005). *How Students Learn: History, Mathematics, and Science in the Classroom*. Washington, DC: The National Academies Press.
- Lantz, H.B. (2004). *Rubrics for Assessing Student Achievement in Science Grades K-12*. Thousand Oaks: Corwin Press.
- Miller, Linn, & Gronlund. (2009). *Measurement and assessment in teaching*. Upper Saddle River, NJ: Pearson.
- National Academies Press. (1996, January 1). *National science education standards*. Retrieved February 7, 2011 from http://www.nap.edu/catalog.php?record_id=4962
- National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Committee on a Conceptual Framework for New K-12 Science Education Standards. Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.
- The Partnership for 21st Century Skills (2011). *A framework for 21st century learning*. Retrieved March 15, 2012 from <http://www.p21.org/>
- Vasquez, J.A., Comer, M.W., & Troutman, F. (2010). *Developing visual literacy in science k-8*. Arlington, VA: NSTA Press.

**(A) Making and Mapping a Volcano (1 of 4)**

Essential Question: How do people reconstruct the date events in Earth's planetary history?

For this activity, you will be placed in the role of a volcanologist. Have you ever wanted to look inside or under a volcano? Have you ever wondered what is there that you cannot see? You will have the opportunity to not only create a volcano, but look inside an unknown volcano to see what its history is. Your mission will include the following 4 tasks:

1. Create a volcano model using baking soda, vinegar, and play dough.
2. Draw a geologic map of your volcano showing the sequence of volcanic events.
3. Use core sampling, road cuts/river cuts, and relative dating principles to determine the sequence of events of another volcano.
4. Observe a real geologic map of Mars and determine the sequence of events only using a bird's eye (map) view.

What is a “geologic map?”

You will be creating something called a geologic map. These are special maps that show certain geologic features such as rocks and faults. Different colors on a geologic map typically show different types of rocks or show the same type of rock, but different events in time. You can also occasionally find lines that represent faults and numbers representing the slope. For this activity today, we will only be concerned with different colors and sequencing of events.

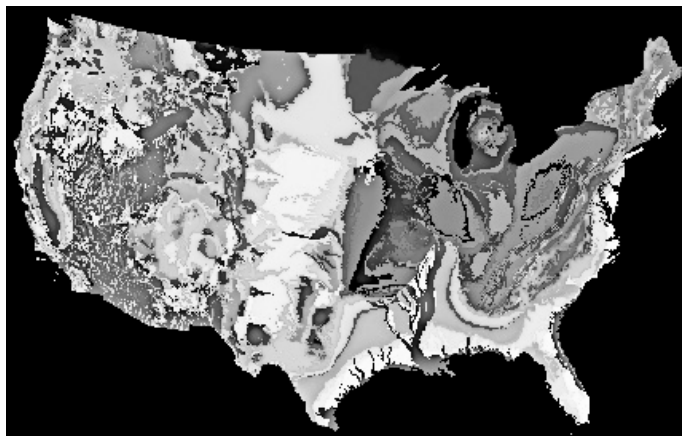


Photo courtesy of US Geological Survey

**LAVA LAYERING****Student Guide****(A) Making and Mapping a Volcano (2 of 4)**

NAME: _____

Before you get started:

Explain what techniques you believe your friends could use to determine the flavorings and sequence within the cake without cutting a slice of the cake.

Materials/Equipment (per group):

- | | |
|---|--|
| <input type="checkbox"/> 1 paper cup, 100ml (3 oz) size, cut down to a height of 2.5cm (~1") measured from the bottom up. | <input type="checkbox"/> Vinegar, 100-150ml (~4 oz) |
| <input type="checkbox"/> 2 cups, 150-200ml (6 - 8 oz) size. | <input type="checkbox"/> Paper towels (~6 sheets) |
| <input type="checkbox"/> Cardboard, ~ 45cm square (can substitute cookie sheet or a box lid) | <input type="checkbox"/> #2 pencil |
| <input type="checkbox"/> Play Dough or soft clay – three - 2 inch (2 oz) balls, each a different color | <input type="checkbox"/> 8 ½ " X 11" Paper |
| <input type="checkbox"/> Tape (Scotch) | <input type="checkbox"/> Colored pencils or crayons |
| <input type="checkbox"/> Spoon | <input type="checkbox"/> 2 Metric rulers |
| <input type="checkbox"/> Baking soda (~1/4 cup) | <input type="checkbox"/> Straight edge for cutting (plastic knife or dental floss) |
| | <input type="checkbox"/> Clear regular drinking straw |
| | <input type="checkbox"/> 5-10 toothpicks |

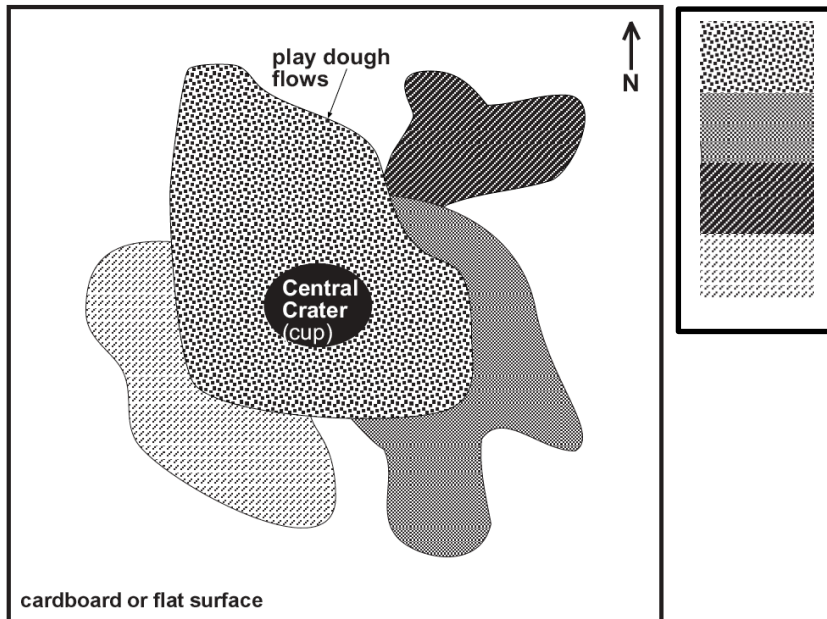
**(A) Making and Mapping a Volcano (3 of 4)****Procedures:**

1. Take one paper cup that has been cut to a height of 2.5cm and secure it onto the cardboard. (You may use a small piece of tape on the outside bottom of the cup.) This short cup is your eruption source (vent) and the cardboard is the original land surface.
2. On the edges of the cardboard, mark North, South, East and West.
3. Fill a large paper cup about $\frac{1}{4}$ full with baking soda (unless your teacher has pre-measured quantities ready for you.)
4. Pour about $\frac{1}{4}$ cup of vinegar into a cup (unless your teacher has pre-measured quantities ready for you). You will use this for all your volcanic eruptions.
5. Place 1 heaping spoonful of baking soda in the short cup in your tray.
6. You are not ready to create an eruption. Slowly pour a small amount of vinegar into your source cup and watch the eruption of simulated "lava."
7. When the lava stops erupting, quickly draw around the flow edge with a pencil.
8. Wipe up the fluid with paper towels and dispose of the paper towels in the trash.
9. As best you can, use a thin layer of play dough to cover the entire area where "lava" flowed.
10. On the student sheet, record information about the flow.
11. Repeat steps 5-10 for each color of play dough available.
12. Wash your hands after you have finished the eruptions.

Eruption #	Color of eruption	Draw the shape of the eruption	Direction of the eruption	Thickness of eruption
1				
2				
3				
4 (optional)				

**(A) Making and Mapping a Volcano (4 of 4)****Bird's Eye (Map) View Drawing:**

Draw your finished volcano from above. Color each layer to match the color of the "lava" flow. Include a geologic column as a key. A geologic column shows the sequence of lava flows from oldest (bottom) to youngest (top). A sample is provided below.

Sample Drawing:

Note: Color has not been included in this sample. Yours should include the color of the lava flow.

Your Drawing and Column:

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**(B) Student Sheet #1 (1 of 2)**

NAME: _____

1. **Observe:** Looking down at your volcano, describe what you see. Include an explanation of where flows occur and in what sequence.

2. **Paths:** Did the flows always follow the same path? What do you think influences the path direction of lava flows?



(B) Student Sheet #1 (2 of 2)

3. **Layering:** If you had not watched the eruptions, how would you know that there are many different layers of lava? What techniques would you try? Could you use these techniques with real lava flows?

4. **Sequencing:** How did you distinguish between older and younger strata (layers)? What techniques would you use to identify the sequence of events? Could these same techniques be use on Earth or Mars? Why or why not?

**(C) Relative Age Dating Technique**

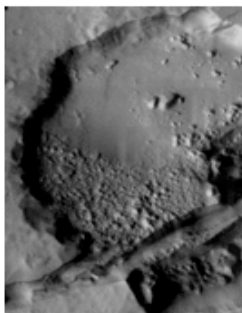
RELATIVE AGE DATING TECHNIQUE

Relative Age Dating Principles

Scientists use two basic rules or principles to help determine the relative age of craters or other features on a surface. They are as follows:

1. Cross-Cutting Relationships:

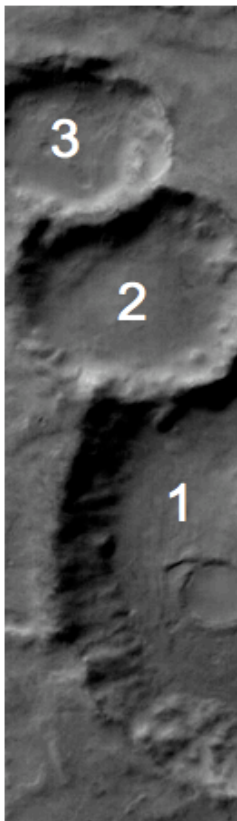
- A crater (or any other feature) can be cut by another feature.
- The feature cut is older than the feature that cut it.



Crater shown here is older than the fracture (crack) that cut through it.

2. Principle of Superposition

- When one feature is on top of another feature, the feature on top is younger.
- The feature on the bottom is the older feature.



Crater #1 is partly covered by crater #2, so crater #1 is older.

Crater #2 is partly covered by crater #3, which makes crater #2 older than #3.

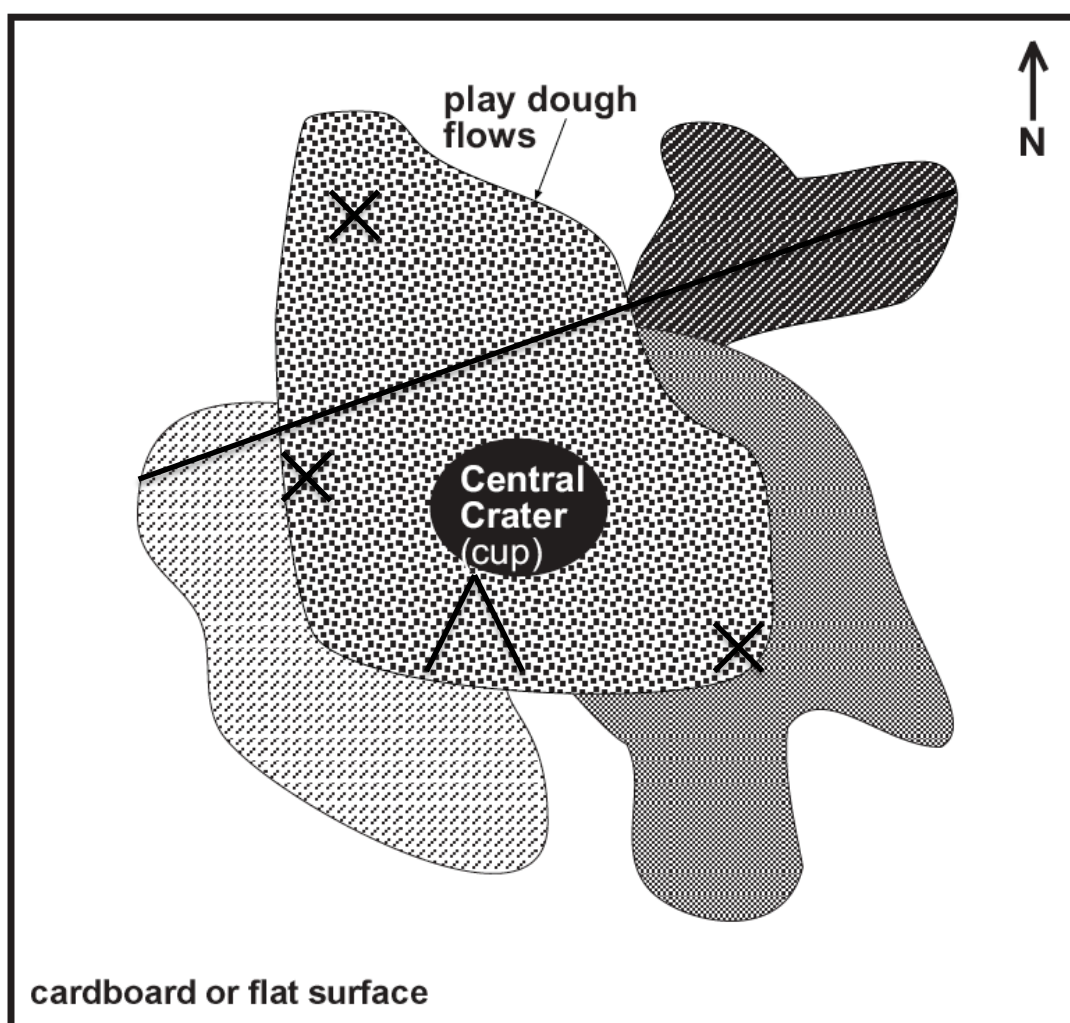
By inference then, crater #1 is the oldest and crater #3 is the youngest.

**(D) Mapping an “Unknown” Volcano (1 of 2)**

NAME: _____

Procedures:

1. Trade your volcano another group so that you each must map a volcano with an “unknown” history.
2. Draw a map (bird’s eye view) of the volcano. The map should include a North direction arrow. Make careful observation and measurements to map the volcanoes accurately.
3. Color and label the map using a key (legend).
4. Make a plan on your map showing where you intend to put the subsurface exposures. Mark 3 drill cores (core samples) with an “X,” draw a straight line across the area you will road cut, and draw a “V” across the area that will be a river erosion (V facing downslope). Your teacher will tell you how many of each you have available. (See example)



**(D) Mapping an “Unknown” Volcano (2 of 2)**

5. Make the cut and cores.
 - a. Remove drill cores by pushing a straw vertically into the play dough, twisting, and withdrawing the straw. Blow through the open end of the straw to remove the core. Put the core on a toothpick and place it by the hole for reference.
 - b. River valleys may be made by cutting and removing a “V” shape in the side of the volcano (open part of the “V” facing down slope).
 - c. To make road cuts, use dental floss to cut and remove a strip about 1 cm wide and as deep as you from any part of the volcano.
6. Observe the hidden layers. Interpret the data and draw dotted lines (with the appropriate colored pencil or crayon) on the map indicating the approximate or inferred boundaries of the subsurface.
7. Once you have made all of your observations, create a geologic column representing the sequence of events (bottom is oldest, top is youngest).
8. Compare the history you have determined with the original group.

Your Drawing and Column:

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(E) Student Sheet #2 (1 of 2)

NAME: _____

1. **Geologic History:** How close was your group in determining the geologic history of the lava flows from the “unknown” volcano? Did you need more information? If given the opportunity, where would you collect additional information? Why?

2. **Techniques:** What are the advantages of knowing the relative dating techniques and tools such as core sampling and road cuts that scientists use?



(E) Student Sheet #2 (2 of 2)

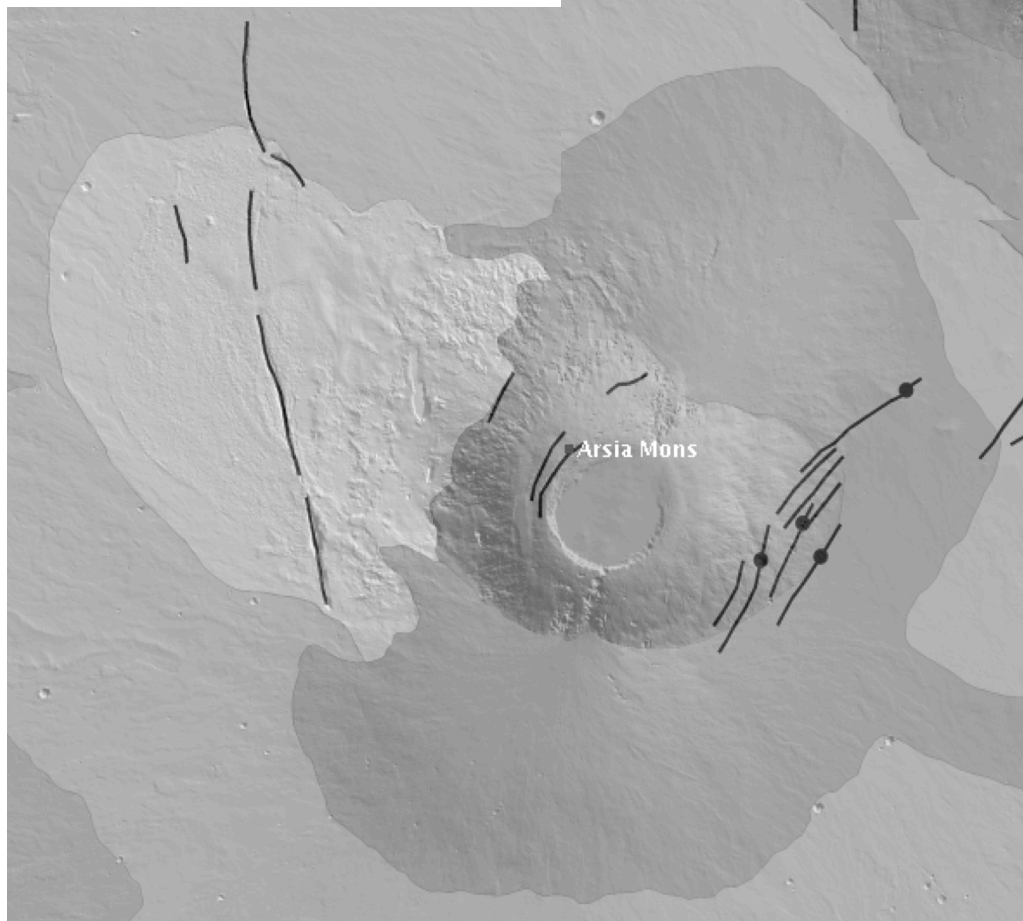
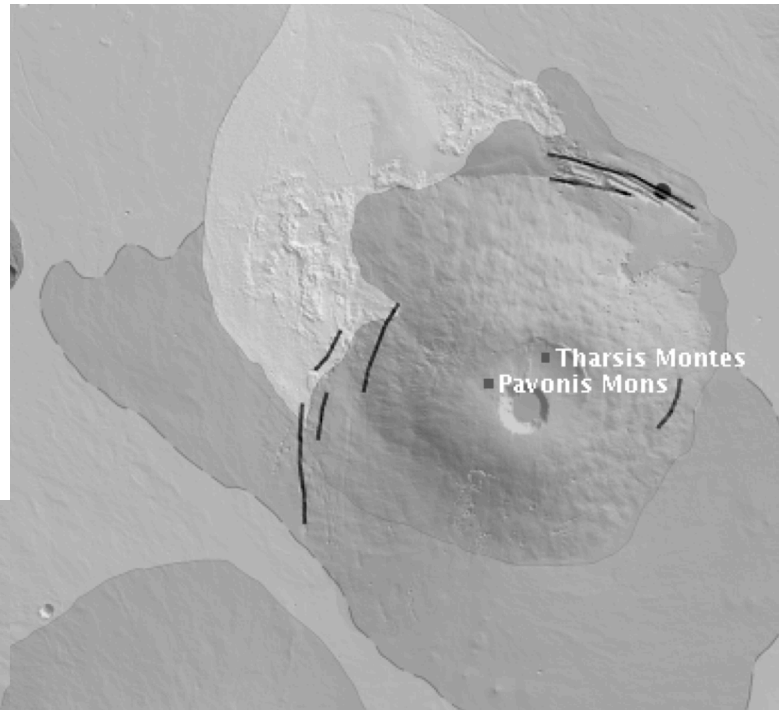
3. **The Cake:** Think back to the story your teacher told you about your friend’s birthday cake. With your new understanding, what techniques would you recommend to your friends to determine the flavors and order of the layers within the cake? Be sure to use the new vocabulary you have learned in your explanation.

4. **Mars:** Why would it be harder to map lava flows on Mars using spacecraft photos?



(F) Geologic Map of Pavonis Mons

Geologic Map courtesy of
Mars Space Flight Facility /
Arizona State University



**(G) Single Sheet Option for Student Sheet #1 and Student Sheet #2**

1. **Observe:** Looking down at your volcano, describe what you see. Include an explanation of where flows occur and in what sequence.
 2. **Paths:** Did the flows always follow the same path? What do you think influences the path direction of lava flows?
 3. **Layering:** If you had not watched the eruptions, how would you know that there are many different layers of lava? What techniques would you try? Could you use these techniques with real lava flows?
 4. **Sequencing:** How did you distinguish between older and younger strata (layers)? What techniques would you use to identify the sequence of events? Could these same techniques be used on Earth or Mars? Why or why not?
-
1. **Geologic History:** How close was your group in determining the geologic history of the lava flows from the “unknown” volcano? Did you need more information? If given the opportunity, where would you collect additional information? Why?
 2. **Techniques:** What are the advantages of knowing the relative dating techniques and tools such as core sampling and road cuts that scientists use?
 3. **The Cake:** Think back to the story your teacher told you about your friend’s birthday cake. With your new understanding, what techniques would you recommend to your friends to determine the flavors and order of the layers within the cake? Be sure to use the new vocabulary you have learned in your explanation.
 4. **Mars:** Why would it be harder to map lava flows on Mars using spacecraft photos?

**(H) Volume Reference Page**

In this activity, it would be important to distinguish between area and volume. While the activity itself really only addresses the area of the lava flow, scientists technically determine the volume of the eruption. This is important data when establishing the overall scale of the eruption.

Scientists will study the volume and morphology of a lava flow by mapping and comparing the topography (the study of the planet's surface shape and features) before and after lava eruption. Contour maps are a widely available source of topographic data, containing a record of changes at volcanoes due to lava eruption.

Below you will find a graphic that demonstrates the difference in volume of different volcanic eruptions to demonstrate the scale of the eruption.

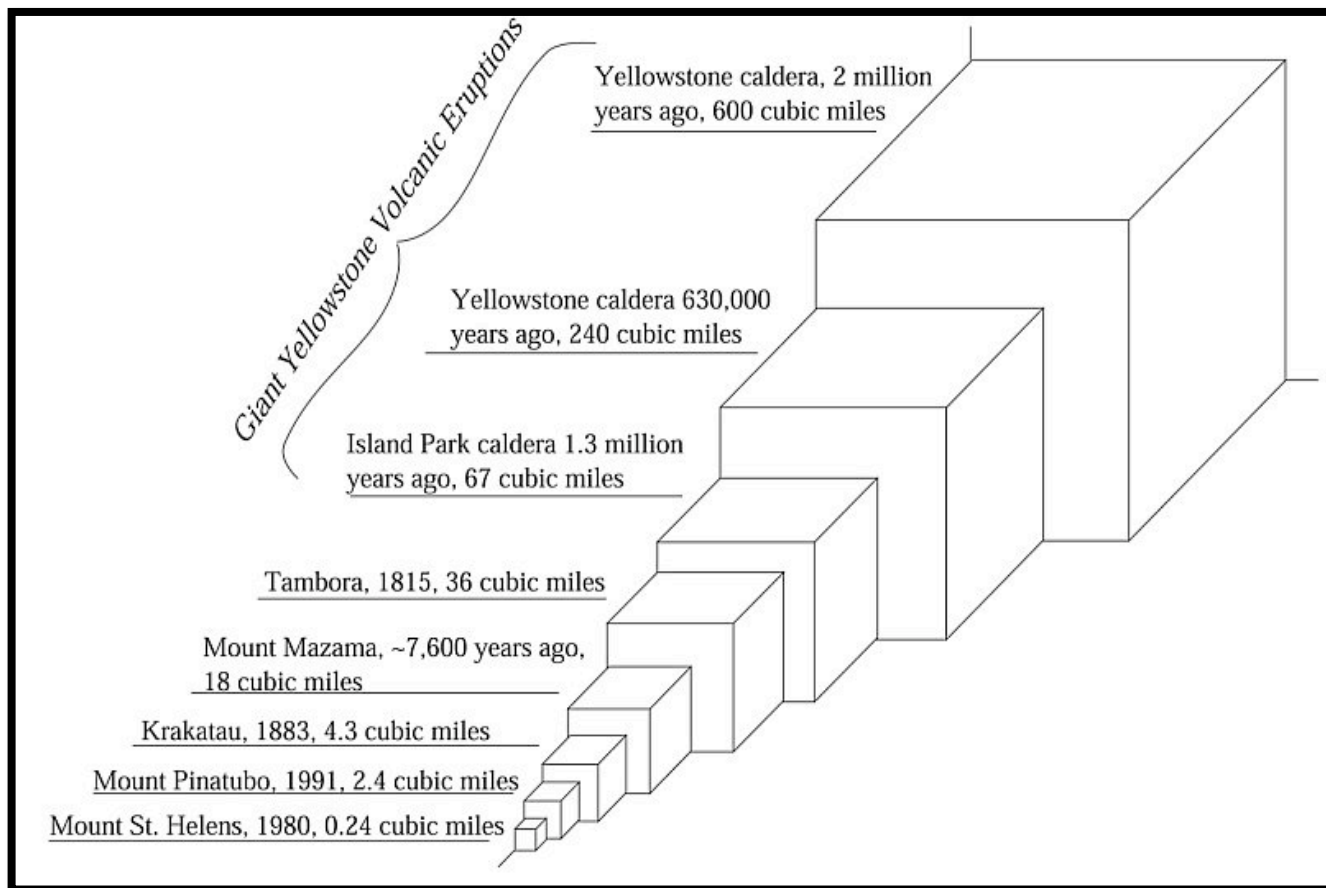


Diagram Courtesy of US Geological Survey



(I) Volcano Science Content Reference Page

Volcanoes and/or lava flows are prominent features on all large rocky planetary bodies. Even some asteroid fragments show evidence of lava flows. Volcanism is one of the major geologic processes in the solar system. Mars has a long history of volcanic activity from the ancient volcanic areas of the southern highlands to the more recent major volcanoes of the Tharsis bulge. Olympus Mons is a volcanic mound over 20km above the surrounding plains. This one volcano would cover the entire state of Arizona.

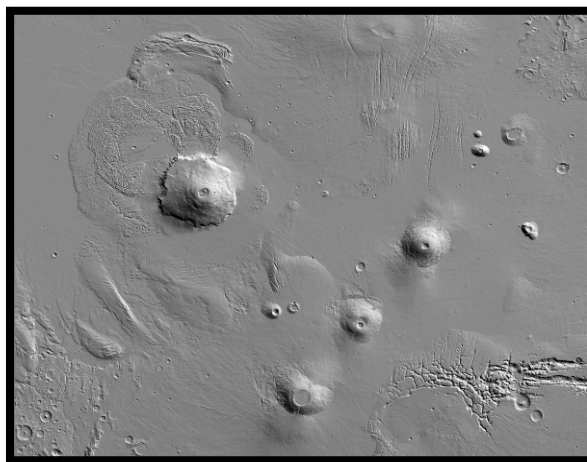
Where volcanic heat and water interact here on Earth, scientists are finding life. In the hot springs of Yellowstone Park they have found abundant life forms including some very small bacteria. There is a possibility that life may have found a place in the ancient volcanic terrain of Mars.

Some of the volcanoes on Mars are **basaltic shield volcanoes** like Earth's Hawaiian Islands. Interpretations of photographs and soil analyses from the Viking (1976) and Pathfinder (1997) missions indicate that many of the lava flows on Mars are probably basalt. Scientists believe that basalt is a very common rock type on all the large bodies of the inner solar system, including Earth.

In addition to shield volcanoes, there are dark, flat layers of basaltic lava flows that cover most of the large basins of Mars and the Earth's moon. The eruption sources for most of the basin lava flows are difficult to identify because source areas have been buried by younger flows.

Generally, the overall slope of the surface, local topographic relief (small cliffs and

depressions), and eruption direction influence the path of lava flows. Detailed maps of the geology of Mars and the Moon from photographs reveal areas of complicated lava layering. The study of rock layering is called **stratigraphy**.



Older flows become covered by younger flows and/or become more pocked with impact craters. Field geologists use difference in roughness, color, and chemistry to differentiate between lava flows. Good orbital images allow them to follow the flow margins, channels, and levees to try to trace lava flows back to the source area.

Photo geologists use pictures taken by planes and spacecraft to interpret the history of a planet's surface. If they can get to the surface, they do field work by making maps and collecting samples. Geologists used pictures taken from Mars orbit to interpret the history of the planet's surface. Soon there will be new data to add to the knowledge of Mars through new orbital spacecraft and lander missions.

**(J) Relative Dating Science Content Reference Page**

Relative dating is also known as stratigraphy. **Stratigraphy** is the science of rock strata, or layers. Layering occurs over time, so rock layers hold the key to understanding the geological events of the past. Here are the four fundamental principles of stratigraphy:

The Principle of Original Horizontality:

When rock layers are laid down on the surface, they form in horizontal layers. This means that non-horizontal rock layers were tilted or folded after they were deposited.

The Principle of Lateral Continuity:

Rock layers typically extend for quite a distance over the surface—from a few meters to hundreds of kilometers, depending on how they were deposited. This is important because scientists can correlate layers at one location to layers at another, sometimes on entirely different continents. This is critical for stratigraphic correlation.



Photo courtesy of NASA

The Principle of Superposition: As layers accumulate through time, older layers are buried beneath younger layers. If geologists can determine which way was originally “up” in a stack of layers, they can put those strata in the correct historical order.

The Principle of Faunal Succession:

Fossils change through a vertical succession (sequence) of rock layers. The same vertical changes in fossils occurred in different places. The observation that fossils change in a consistent manner through stratigraphic successions can be extended to the entire world.

Scientists can use tools to determine the stratigraphy of an area. Some of these tools are man-made while others are natural. These are **outcrops and cores**.

Cores can also be called **Drill Cores** or **Core Samples**. Cores are a sample of rock, soil, snow, or ice that can be collected by driving a large hollow tube down into the crust or undisturbed material, then pulling out the sample. Cores can show a variation in rock types in a vertical column and allow us to see what layers are below the surface that we cannot see.

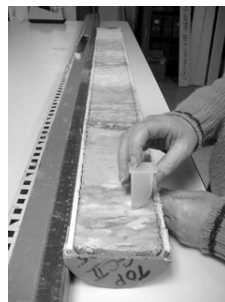


Photo Courtesy of University of Oregon College of Oceanic and Atmospheric Sciences

Outcrops are breaks in the surface. **Natural outcrops** include streambeds, cliffs, caverns or fault blocks. These are exposed from weathering and erosion and will show the stratigraphy of an area. **Man-made outcrops** consist of road cuts for highways that behave like a scalpel.

Teacher Guide

	GRAND CANYON NATIONAL PARK ARIZONA	ZION NATIONAL PARK UTAH	CANYONLANDS NATIONAL PARK UTAH	MESA VERDE NATIONAL PARK COLORADO	BRYCE CANYON NATIONAL PARK UTAH
TERTIARY PERIOD					
CRETACEOUS PERIOD					
JURASSIC PERIOD					
TRIASSIC PERIOD					
PERMIAN PERIOD					
PENNSYLVANIAN PERIOD					
MISSISSIPPIAN PERIOD					
DEVONIAN PERIOD*					
CAMBRIAN PERIOD					
PRECAMBRIAN PERIOD					

*Rocks of Ordovician and Silurian age not present in Grand Canyon

Ss-Sandstone; Fm-Formation; Ls-Limestone

Image courtesy of US Geological Survey

On behalf of NASA's Mars Exploration Program, this lesson was prepared by Arizona State University's Mars Education Program, under contract to NASA's Jet Propulsion Laboratory, a division of the California Institute of Technology. These materials may be distributed freely for non-commercial purposes. Copyright 2012; 2010; 2000.

**(L) Teacher Resource. Lava Layering Rubric (1 of 3)**

You will know the level to which your students have achieved the **Learning Outcomes**, and thus the **Instructional Objective(s)**, by using the suggested **Rubrics** below.

Instructional Objective 1: to reconstruct geologic events of a series of lava flows using relative dating techniques

Related Standard(s) (will be replaced when new NRC Framework-based science standards are released):

**National Science Education Standards (NSES)
UNIFYING CONCEPTS & PROCESSES****Grades K-12: Evidence, models, and explanations**

Evidence consists of observations and data on which to base scientific explanations. Using evidence to understand interactions allows individuals to predict changes in natural and designed systems. Models are tentative schemes or structures that correspond to real objects, events, or classes of events, and that have explanatory power. Models help scientists and engineers understand how things work. Models take many forms, including physical objects, plans, mental constructs, mathematical equations, and computer simulations.

Scientific explanations incorporate existing scientific knowledge and new evidence from observations, experiments, or models into internally consistent, logical statements. Different terms, such as "hypothesis," "model," "law," "principle," "theory," and "paradigm" are used to describe various types of scientific explanations.

As students develop and as they understand more science concepts and processes, their explanations should become more sophisticated. That is, their scientific explanations should more frequently include a rich scientific knowledge base, evidence of logic, higher levels of analysis, greater tolerance of criticism and uncertainty, and a clearer demonstration of the relationship between logic, evidence, and current knowledge.

National Science Education Standards (NSES)**(A) Science as Inquiry: Understandings about Scientific Inquiry**

Different kinds of questions suggest different kinds of scientific investigations. Some investigations involve observing and describing objects, organisms, or events; some involve collecting specimens; some involve experiments; some involve seeking more information; some involve discovery of new objects and phenomena; and some involve making models (Grades 5-8: A2a).

National Science Education Standards (NSES)**(D) Earth and Space Science: Structure of the Earth System**

Landforms are the result of a combination of constructive and destructive forces. Constructive forces include crustal deformation, volcanic eruption, and depositions of sediment, while destructive forces include weathering and erosion (Grades 5-8: D1c).

**Related Rubrics for the Assessment of Learning Outcomes Associated with the Above Standard(s):**

Learning Outcome	Expert	Proficient	Intermediate	Beginner
LO1a: to construct a geologic map of a volcano model	Maps accurately and effectively communicate layering structure of the volcano model.	Maps accurately communicate the layering structure of the volcano model.	Maps communicate layering of the volcano model.	Maps demonstrate a volcano model.

**(L) Teacher Resource. Lava Layering Rubric (2 of 3)**

Related Standards (will be replaced when new NRC Framework-based science standards are released):

National Science Education Standards (NSES)
UNIFYING CONCEPTS & PROCESSES

Grades K-12: Evidence, models, and explanations

Evidence consists of observations and data on which to base scientific explanations. Using evidence to understand interactions allows individuals to predict changes in natural and designed systems. Models are tentative schemes or structures that correspond to real objects, events, or classes of events, and that have explanatory power. Models help scientists and engineers understand how things work. Models take many forms, including physical objects, plans, mental constructs, mathematical equations, and computer simulations.

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National Science Education Standards (NSES)

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National Science Education Standards (NSES)

(D) Earth and Space Science: Structure of the Earth System

Landforms are the result of a combination of constructive and destructive forces. Constructive forces include crustal deformation, volcanic eruption, and depositions of sediment, while destructive forces include weathering and erosion (Grades 5-8: D1c).



Related Rubrics for the Assessment of Learning Outcomes Associated with the Above Standard(s):

Learning Outcome	Expert	Proficient	Intermediate	Beginner
LO1b. to use geologic sampling and relative dating techniques	Model utilizes all materials effectively and as directed by the facilitator. Sampling techniques are used thoughtfully with the intention of collecting the most information.	Model uses all materials and follows facilitator instructions. Sampling techniques are used with some thought to appropriate placement for quality information.	Model uses all materials and/or sampling techniques are used with some thought to appropriate placement.	Materials usage and/or sampling technique is based on student preference and desires.

**(L) Teacher Resource. Lava Layering Rubric (3 of 3)****National Science Education Standards (NSES)
UNIFYING CONCEPTS & PROCESSES****Grades K-12: Evidence, models, and explanations**

Evidence consists of observations and data on which to base scientific explanations. Using evidence to understand interactions allows individuals to predict changes in natural and designed systems. Models are tentative schemes or structures that correspond to real objects, events, or classes of events, and that have explanatory power. Models help scientists and engineers understand how things work. Models take many forms, including physical objects, plans, mental constructs, mathematical equations, and computer simulations.

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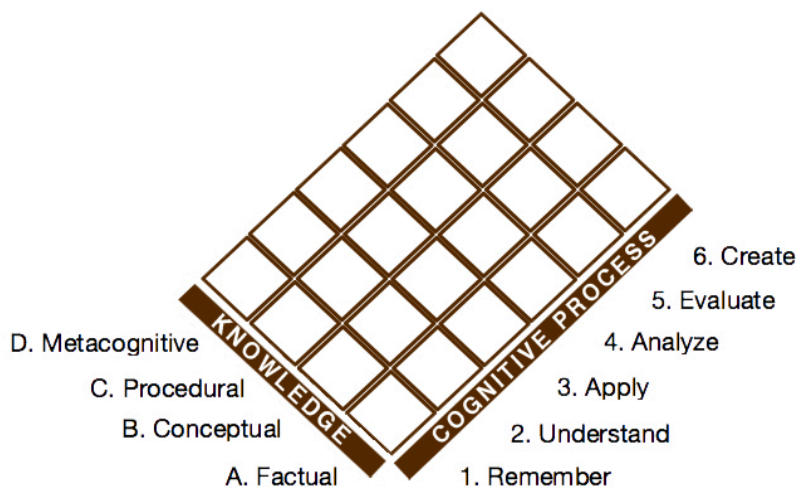


Related Rubrics for the Assessment of Learning Outcomes Associated with the Above Standard(s)

Learning Outcome	Expert	Proficient	Intermediate	Beginner
LO1c. to justify an explanation for the geologic mapping and history of the volcano model	Student is able to identify and explain the strong connection between sampling techniques and development of a geologic map.	Student is able to identify and explain the connection between sampling techniques and geologic mapping.	Student is able to identify the connection between sampling techniques and geologic mapping.	Student explains sampling techniques separately from geologic mapping.



(M) Teacher Resource. Placement of Instructional Objective and Learning Outcomes in Taxonomy (1 of 3)



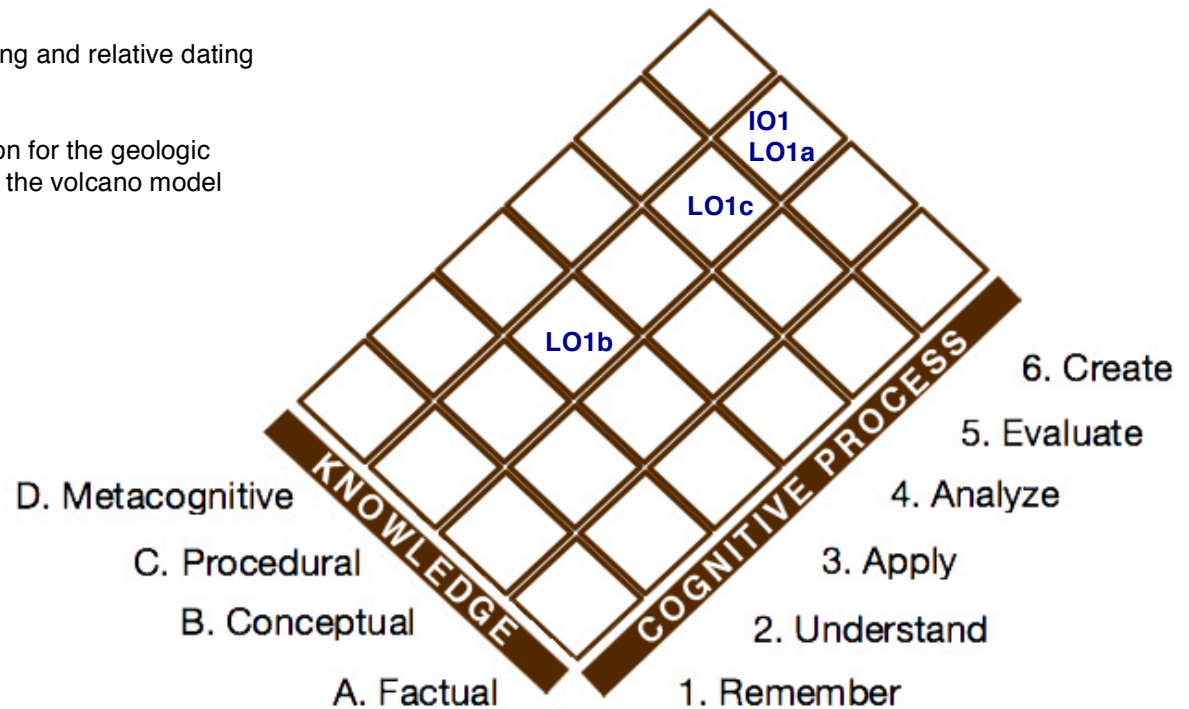
This lesson adapts Anderson and Krathwohl's (2001) taxonomy, which has two domains: Knowledge and Cognitive Process, each with types and subtypes (listed below). Verbs for objectives and outcomes in this lesson align with the suggested knowledge and cognitive process area and are mapped on the next page(s). Activity procedures and assessments are designed to support the target knowledge/cognitive process.

Knowledge	Cognitive Process
A. Factual Aa: Knowledge of Terminology Ab: Knowledge of Specific Details & Elements B. Conceptual Ba: Knowledge of classifications and categories Bb: Knowledge of principles and generalizations Bc: Knowledge of theories, models, and structures C. Procedural Ca: Knowledge of subject-specific skills and algorithms Cb: Knowledge of subject-specific techniques and methods Cc: Knowledge of criteria for determining when to use appropriate procedures D. Metacognitive Da: Strategic Knowledge Db: Knowledge about cognitive tasks, including appropriate contextual and conditional knowledge Dc: Self-knowledge	1. Remember 1.1 Recognizing (Identifying) 1.2 Recalling (Retrieving) 2. Understand 2.1 Interpreting (Clarifying, Paraphrasing, Representing, Translating) 2.2 Exemplifying (Illustrating, Instantiating) 2.3 Classifying (Categorizing, Subsuming) 2.4 Summarizing (Abstracting, Generalizing) 2.5 Inferring (Concluding, Extrapolating, Interpolating, Predicting) 2.6 Comparing (Contrasting, Mapping, Matching) 2.7 Explaining (Constructing models) 3. Apply 3.1 Executing (Carrying out) 3.2 Implementing (Using) 4. Analyze 4.1 Differentiating (Discriminating, distinguishing, focusing, selecting) 4.2 Organizing (Finding coherence, integrating, outlining, parsing, structuring) 4.3 Attributing (Deconstructing) 5. Evaluate 5.1 Checking (Coordinating, Detecting, Monitoring, Testing) 5.2 Critiquing (Judging) 6. Create 6.1 Generating (Hypothesizing) 6.2 Planning (Designing) 6.3 Producing (Constructing)

**(M) Teacher Resource. Placement of Instructional Objective and Learning Outcomes in Taxonomy (2 of 3)**

The design of this activity leverages Anderson & Krathwohl's (2001) taxonomy as a framework. Pedagogically, it is important to ensure that objectives and outcomes are written to match the knowledge and cognitive process students are intended to acquire.

- IO 1:** to **reconstruct** geologic events of a series of lava flows using relative dating techniques (6.3; Cb)
- LO1a:** to **construct** a geologic map of a volcano model (6.3; Cb)
- LO1b:** to **use** geologic sampling and relative dating techniques (3.2; Cb)
- LO1c:** to **justify** an explanation for the geologic mapping and history of the volcano model (5.2; Cb)



**(M) Teacher Resource. Placement of Instructional Objective and Learning Outcomes in Taxonomy (3 of 3)**

The design of this activity leverages Anderson & Krathwohl's (2001) taxonomy as a framework. Below are the knowledge and cognitive process types students are intended to acquire per the instructional objective(s) and learning outcomes written for this lesson. The specific, scaffolded 5E steps in this lesson (see 5.0 Procedures) and the formative assessments (worksheets in the Student Guide and rubrics in the Teacher Guide) are written to support those objective(s) and learning outcomes. Refer to (E, 1 of 3) for the full list of categories in the taxonomy from which the following were selected. The prior page (E, 2 of 3) provides a visual description of the placement of learning outcomes that enable the overall instructional objective(s) to be met.

At the end of the lesson, students will be able

**IO1: to reconstruct geologic events of
a series of lava flows using
relative dating techniques**

6.3: to construct

Cb: knowledge of subject-specific
techniques and methods

To meet that instructional objective, students will demonstrate the abilities:

**LO1a: to construct a geologic map of a
volcano model**

6.3: to construct

Cb: knowledge of subject-specific
techniques and methods

**LO1b: to use geologic sampling and
relative dating techniques**

3.2: to use

Cb: knowledge of subject-specific
techniques and methods

**LO1c: to justify an explanation for the
geologic mapping and history of
the volcano model**

5.2: to justify

Cb: knowledge of subject-specific
techniques and methods